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Effect of Dissociation Pulse Circuit Inductance on the CuCl Laser

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Abstract—**The performance of the double-pulsed CuCl laser is improved by a decrease in the inductance of the dissociation pulse circuit. Higher efficiency is obtained due to a larger ground state copper atom population and lower optimum dissociation energy.**

EFFICIENT pumping of the copper atoms in a cuprous chloride laser requires short, fast-rising current pulses [1], but it is not known if this type of current pulse efficiently dissociates CuCl molecules. Previous experimental work on the dissociation pulse of a double-pulsed CuCl laser [2] indicated that the laser energy was dependent only on the energy in that pulse. In that study, the dissociation pulse was altered by changing the storage capacitance and the capacitor voltage; added capacitance increases the peak current and lengthens the pulse while maintaining the same initial current rise; increased voltage increases the peak current and the initial current rise while leaving the pulsewidth approximately unchanged. In the present work, the dissociation pulse was altered by adding inductance to the discharge circuit; the added inductance reduced the initial current rise, reduced the peak current, and lengthened the pulse. This study demonstrated large effects on laser energy as well as variations of the characteristic delay times.

The experimental apparatus and methods are described in detail elsewhere [1]. The components of the double-pulsed power supply were rearranged to lower the circuit inductance to 0.5 μH. The laser tubes were 10 mm in diameter and had a 300-mm separation between electrodes. The tube temperature was approximately 400°C, and neon was used as a buffer gas at a pressure of about 1 kPa. For these experiments air core coils were added between the dissociation pulse circuitry and the laser tube electrode in the same manner as used previously

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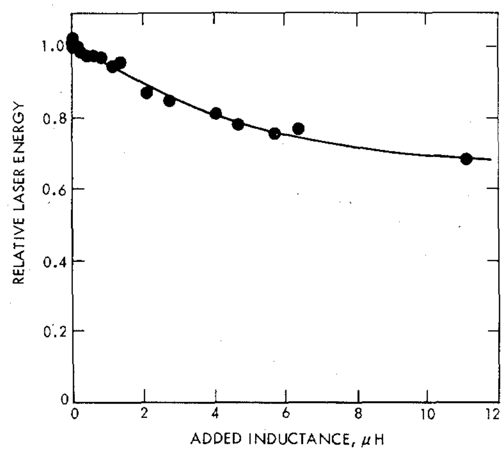

Fig. 1. Relative laser energy as a function of inductance added to the dissociation pulse circuit. Dissociation pulse energy was 2.9 J.

[1]. The pumping pulse remained at 1.4 J (7.2 nF at 20 kV) for this study.

A series of experiments were conducted at a constant value of 2.9-J dissociation energy, which was the optimum for the condition of no added inductance. As shown in Figs. 1 and 2, the laser energy and the characteristic time delays decreased when inductance was added to the dissociation pulse circuit. The laser energy decreased with increasing circuit inductance at almost all values of the dissociation energy.

The dependence of laser energy on the dissociation energy is shown in Fig. 3 for two values of circuit inductance, about 0.5 μH for no added coil and 4.5 μH for a 4-μH coil added. For each circuit inductance there was an optimum value for the dissociation energy; the optimum value is not sharply defined but it increased when the 4-μH coil was added. Fig. 3 illustrates that at a fixed inductance the laser energy is not a strong function of the capacitance or the capacitor voltage, but depends only on the dissociation energy; this is a relation which was determined previously [2].

It was found that part of the laser energy loss that resulted from the added inductance could be recovered by increasing the dissociation energy; consequently, the dissociation energy

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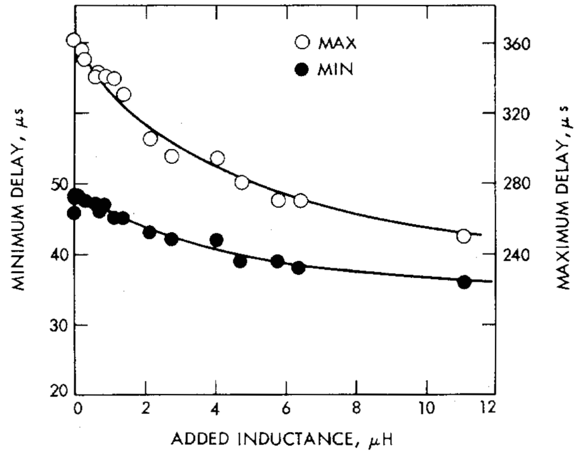

Fig. 2. Minimum and maximum time delays as a function of inductance added to the dissociation pulse circuit. These data correspond to the data presented in Fig. 1.

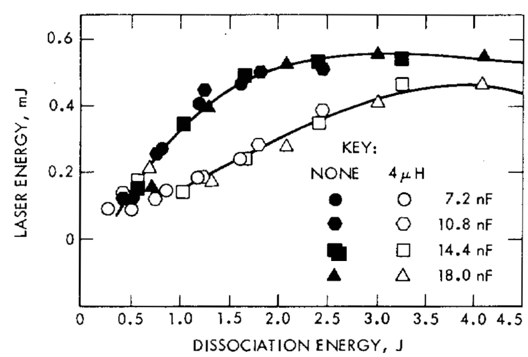

Fig. 3. Laser energy as a function of the dissociation pulse energy with no coil and with a 4-μH coil added to the dissociation pulse circuit.

was optimized at each value of added inductance in another series of experiments. As an example of the performance improvement, with a 4-μH inductor the decrease was 20 percent at constant dissociation energy but only 8 percent with optimized dissociation energy. The optimum dissociation energy increased with increasing inductance; for the 11-μH inductor the optimum dissociation energy was seven times larger than that required when no inductor was added. As the circuit inductance was increased, the minimum and optimum time delays increased and the maximum time delay decreased. With the 11-μH coil the maximum time delay decreased 7 percent and the minimum time delay increased about 50 percent relative to the condition with no added inductance. These changes can be compared to a 30 percent decrease in the maximum time delay and a 25 percent decrease in the minimum time delay at constant dissociation energy.

From the results of previous studies [3], [4], it is known that the minimum time delay is associated with the time required for the copper metastable level population density to decay. At fixed tube geometry, temperature, and buffer gas pressure, any increase in the production of copper metastable atoms is accompanied by an increase in the minimum time delay. Also, the maximum time delay is associated with the decay of the copper ground state population density and an increase in the number of ground state atoms results in an increase of the maximum delay. Although it was not possible to control the production of these two species independently, it is clear that the threshold condition at the minimum time delay, as well as the conditions that produce maximum energy at the optimum time delay, depend on the density of both the ground state and metastable level densities.

Based on these correlations, it is concluded here that the major effect of the added inductance is to diminish the effectiveness of the dissociation pulse to produce copper ground state atoms. The reduced maximum time delay implies reduced copper ground state population. Because the ground state population density is lower, the reduced minimum time delay which occurred with constant dissociation energy implies that the metastable level population density is also lower. With optimized dissociation energy, the maximum time delay decreases slightly, indicating that the ground state population density decreases only slightly; the large increase in the minimum time delay is therefore attributed to a significant increase in the metastable level population density.

These experiments indicate that the performance of the double-pulsed CuCl laser is improved by a decrease in the inductance of the dissociation pulse circuit. The decrease in inductance provides higher efficiency in two ways: a larger ground state copper atom population after the dissociation pulse and a lower optimum dissociation energy. The loss of performance due to inductance cannot by fully compensated by an increase in the dissociation pulse energy.

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